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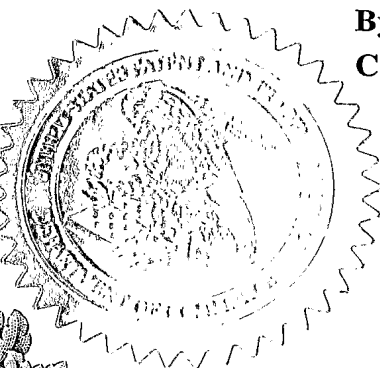
APPLICATION NUMBER: 60/540,378

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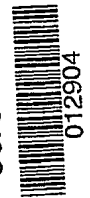
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**PROVISIONAL APPLICATION FOR PATENT COVER SHEET**

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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13441 U.S. PTO  
60/540378



INVENTOR(S)					
Given Name (first and middle [if any])		Family Name or Surname		Residence (City and either State or Foreign Country)	
Pen c.		Li		San Jose, CA	
Additional inventors are being named on the _____ separately numbered sheets attached hereto					
TITLE OF THE INVENTION (500 characters max)					
Enhanced Spectral Keying For Wireless Ultra Wideband Comm.					
Direct all correspondence to: CORRESPONDENCE ADDRESS					
<input checked="" type="checkbox"/> Customer Number: <u>24738</u>					
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ENCLOSED APPLICATION PARTS (check all that apply)					
<input checked="" type="checkbox"/> Specification Number of Pages <u>11</u>					
<input type="checkbox"/> CD(s), Number _____					
<input checked="" type="checkbox"/> Drawing(s) Number of Sheets <u>3</u>					
<input checked="" type="checkbox"/> Other (specify) <u>2 return post cards</u>					
<input type="checkbox"/> Application Date Sheet. See 37 CFR 1.76					
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT					
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27.					
<input checked="" type="checkbox"/> A check or money order is enclosed to cover the filing fees.					
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FILING FEE Amount (\$) <u>160-</u>					
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
<input checked="" type="checkbox"/> No.					
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[Page 1 of 2]

Respectfully submitted,

SIGNATURE

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TYPED or PRINTED NAME

Raymond J. Werner

TELEPHONE

503-466-2294

Date

29 January 2004

REGISTRATION NO.

34,752

(if appropriate)

Docket Number

US 04 0095P

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# FEE TRANSMITTAL for FY 2004

Effective 10/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT

(\$) 160-

C mplete if Kn wn

Application Number

Unknown

Filing Date

29 January 2004

First Named Inventor

Pen C. Li

Examiner Name

Unknown

Art Unit

unknown

Attorney Docket No.

USOA 0095 P

## METHOD OF PAYMENT (check all that apply)

☒ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☐ Deposit Account:

Deposit  
Account  
Number  
Deposit  
Account  
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The Director is authorized to: (check all that apply)

☐ Charge fee(s) indicated below ☐ Credit any overpayments

☐ Charge any additional fee(s) or any underpayment of fee(s)

☐ Charge fee(s) indicated below, except for the filing fee to the above-identified deposit account.

## FEE CALCULATION

### 1. BASIC FILING FEE

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
1001 770	2001 385	Utility filing fee	
1002 340	2002 170	Design filing fee	
1003 530	2003 265	Plant filing fee	
1004 770	2004 385	Reissue filing fee	
1005 160	2005 80	Provisional filing fee	160

SUBTOTAL (1) (\$) 160-

### 2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

Total Claims	Extra Claims	Fee from below	Fee Paid
Independent	-20** =	X	
Multiple Dependent	-3** =	X	

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description
1202 18	2202 9	Claims in excess of 20
1201 86	2201 43	Independent claims in excess of 3
1203 290	2203 145	Multiple dependent claim, if not paid
1204 86	2204 43	** Reissue independent claims over original patent
1205 18	2205 9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) (\$) 0

\*\*or number previously paid, if greater; For Reissues, see above

## FEE CALCULATION (continued)

### 3. ADDITIONAL FEES

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
1051 130	2051 65	Surcharge - late filing fee or oath	
1052 50	2052 25	Surcharge - late provisional filing fee or cover sheet	
1053 130	1053 130	Non-English specification	
1812 2,520	1812 2,520	For filing a request for ex parte reexamination	
1804 920*	1804 920*	Requesting publication of SIR prior to Examiner action	
1805 1,840*	1805 1,840*	Requesting publication of SIR after Examiner action	
1251 110	2251 55	Extension for reply within first month	
1252 420	2252 210	Extension for reply within second month	
1253 950	2253 475	Extension for reply within third month	
1254 1,480	2254 740	Extension for reply within fourth month	
1255 2,010	2255 1,005	Extension for reply within fifth month	
1401 330	2401 165	Notice of Appeal	
1402 330	2402 165	Filing a brief in support of an appeal	
1403 290	2403 145	Request for oral hearing	
1451 1,510	1451 1,510	Petition to institute a public use proceeding	
1452 110	2452 55	Petition to revive - unavoidable	
1453 1,330	2453 665	Petition to revive - unintentional	
1501 1,330	2501 665	Utility issue fee (or reissue)	
1502 480	2502 240	Design issue fee	
1503 640	2503 320	Plant issue fee	
1460 130	1460 130	Petitions to the Commissioner	
1807 50	1807 50	Processing fee under 37 CFR 1.17(q)	
1806 180	1806 180	Submission of Information Disclosure Stmt	
8021 40	8021 40	Recording each patent assignment per property (times number of properties)	
1809 770	2809 385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810 770	2810 385	For each additional invention to be examined (37 CFR 1.129(b))	
1801 770	2801 385	Request for Continued Examination (RCE)	
1802 900	1802 900	Request for expedited examination of a design application	

Other fee (specify)

\*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) (\$) 0

## SUBMITTED BY

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Date

29 Jan. 2004

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# ENHANCED SPECTRAL KEYING FOR WIRELESS ULTRA WIDEBAND COMMUNICATIONS

5                    Inventor:     Pen C. Li

## Field of the Invention

The present invention relates generally to wireless communication, and more particularly relates to spectral keying in ultra wideband communications.

10

## Background

Ultra wideband (UWB) communications are a form of radio communication in which a signal is spread over a large portion of the radio spectrum, and in which the signal power at any particular frequency is therefore relatively small. The bandwidth of such systems is typically greater than 500MHz, and in some UWB systems the bandwidth may be, for example, between 2GHz and 100GHz. Early UWB systems imparted information to their signals through the use of pulse position modulation. Such pulse position modulation is sometimes referred to in the context of UWB systems as time modulation.

20            By slightly changing the pulse position, that is, the time at which a pulse occurs, information can be encoded into, and subsequently derived from, a UWB signal. For example, a slightly early pulse may be interpreted as a "zero", while a slightly delayed pulse may be interpreted as a "one". Unfortunately, this only provides one bit of information per transmitted pulse.

25            What is needed are methods and apparatus for increasing the information content of ultra wideband signalling schemes.

## Summary of the Invention

Briefly, the amount of information encoded by spectral keying into a UWB symbol having a plurality of modulation symbol times, is increased by operating two or

more frequency band carriers simultaneously during at least one of a plurality of modulation symbol times. In one aspect of the present invention, once a frequency resource, such as a carrier, has been used during a given modulation symbol time, those frequency resources are not used again within that UWB symbol.

5

### Brief Description of the Drawings

Fig. 1 is a frequency versus time diagram illustrating one scheme for transmission of symbols in a known ultra wideband communication system.

10 Fig. 2 is a frequency versus time diagram illustrating a scheme for transmission of symbols in an ultra wideband communication system in accordance with the present invention.

Fig. 3 is a flow diagram illustrating a method in accordance with the present invention.

15

### Detailed Description

Generally, the present invention relates to methods and apparatus for increasing the information content of ultra wideband signalling schemes. More particularly, the present invention relates to spectral keying in an ultra wideband communication system wherein more than one carrier can be turned on at any given time.

20

Reference herein to "one embodiment", "an embodiment", or similar formulations, means that a particular feature, structure, operation, or characteristic described in connection with the embodiment, is included in at least one embodiment of the present invention. Thus, the appearances of such phrases or formulations herein are not necessarily all referring to the same embodiment. Furthermore, various particular features, structures, operations, or characteristics may be combined in any suitable manner in one or more embodiments.

25

Embodiments of the present invention provide advantages with respect to previous spectral keying schemes by allowing more than one carrier to be turned on at any given time. Such previous spectral keying schemes use permutations of available carriers to represent UWB symbols. Embodiments of the present invention take  
5 advantage of combinations of carrier frequencies, in addition to permutations, thereby allowing more information bits to be packed within the same bandwidth. UWB symbols can be represented by the same number of "on" carriers, except that embodiments of the present invention allow multiple carriers to be "on" at the same time.

Referring to Fig. 1, a frequency versus time diagram illustrating one scheme for  
10 transmission of symbols in a known ultra wideband communication system is shown. More particularly, Fig. 1 illustrates an example in which two UWB symbols are transmitted, the UWB symbols each having three frequency bands and three modulation symbols. This is referred to generally as spectral keying. It can be seen in Fig. 1 that each UWB symbol is made up of three modulation symbol times (i.e.,  $t_1$ ,  $t_2$ ,  
15 and  $t_3$ ); and that the UWB symbols are separated from each other by a guard time. In this illustrative example, only one carrier (i.e.,  $f_1$ ,  $f_2$  or  $f_3$ ) can be turned on to transmit a modulation symbol. Once a carrier has been turned on, it cannot be turned on again in that UWB symbol. As illustrated in Fig. 1, the first UWB symbol consists of frequency band  $f_3$  at time  $t_1$ , frequency band  $f_1$  at time  $t_2$ , and frequency band  $f_2$  at time  $t_3$ . This  
20 can be expressed in a convenient notation as  $f_3@t_1$ ,  $f_1@t_2$ , and  $f_2@t_3$ . A further notational simplification is to express the three modulation symbol times as  $\{3,1,2\}$ , where it is understood that the numbers of the triplet represent which one of the three carriers is turned on respectively at times  $t_1$ ,  $t_2$ , and  $t_3$ . Still referring to Fig. 1, the second UWB symbol shown consists of frequency band  $f_2$  at time  $t_1$ , frequency band  $f_3$   
25 at time  $t_2$ , and frequency band  $f_1$  at time  $t_3$ . In accordance with the simplified notation described above, the second UWB symbol may be represented as  $\{2,3,1\}$ .

In order to calculate the number of bits packed into one UWB symbol as illustrated in Fig. 1, assume BPSK is used for modulation. It can be shown that there are three bits as the result of BPSK modulation, while there are  $\log_2(3!) = 2.58$  bits as  
30 the result of permutation. Therefore the total number of information bits is 5.58. As can be seen from the foregoing, spectral keying as illustrated in Fig. 1 gives an

additional  $\log_2(n!)$  bits assuming that the number of frequency carriers is equal to the number of modulation symbols in the UWB symbol, and that number is represented by  $n$ .

Referring to Fig. 2, a frequency versus time diagram illustrating a scheme for transmission of UWB symbols in accordance with the present invention is shown. More particularly, Fig. 2 illustrates an example in which two UWB symbols are transmitted, the UWB symbols each having three frequency bands and three modulation symbols. This is referred to generally as enhanced spectral keying. It can be seen in Fig. 2 that each UWB symbol is made up of three modulation symbol times (i.e.,  $t_1$ ,  $t_2$ , and  $t_3$ ); and that the UWB symbols are separated from each other by a guard time. In this illustrative example of the present invention, more than one carrier (i.e.,  $f_1$ ,  $f_2$  or  $f_3$ ) can be turned on to transmit a modulation symbol. In this embodiment of the present invention, once a carrier has been turned on in a given UWB symbol, it cannot be turned on again in that UWB symbol. As illustrated in Fig. 2, the first UWB symbol consists of frequency band  $f_2$  and frequency band  $f_3$  at time  $t_1$ ; frequency band  $f_1$  at time  $t_2$ ; and none of the frequency band carriers are turned on at time  $t_3$ . This can be expressed in a convenient notation as  $\{(2,3),1,0\}$ , where it is understood that the numbers of this notation represent which one, or ones, of the three carriers are turned on respectively at times  $t_1$ ,  $t_2$ , and  $t_3$ , and where 0 represents that all the frequency band carriers are in an "off" state. Still referring to Fig. 2, the second UWB symbol shown consists of no frequency band carriers being turned on at time  $t_1$ ; frequency band  $f_3$  at time  $t_2$ ; and frequency band  $f_1$  and frequency band  $f_2$  at time  $t_3$ . In accordance with the simplified notation described above, the second UWB symbol may be represented as  $\{0,3,(1,2)\}$ .

It is noted that although the enhanced spectral keying of the present invention contemplates a modulation symbol time within the UWB symbol time in which no frequency carrier is turned on, no modulation information is lost as a result because there are still three "on" carriers in each UWB symbol. It is noted that carriers  $f_1$ ,  $f_2$ , and  $f_3$ , may transmit at frequency bands that are contiguous with each other, or they may be separated from each other by any arbitrary amount. It is further noted that the choice of three carriers and three time slots is for illustrative purposes and is not intended as a limitation on the number of carriers or time slots.

To calculate the number of information bits in one UWB symbol formed in accordance with the enhanced spectral keying of the present invention and wherein for illustrative purposes there are three frequency carriers and three modulation symbol times, the combinations with only one frequency carrier turned on at a time are determined, the combinations with a maximum of two frequency carriers turned on at a time are determined, and the combinations with a maximum of three frequency carriers turned on at a time are determined. The number of combinations are added to produce a "total", and a value for  $\log_2(\text{total})$  is determined.

The combinations described above are enumerated below. The combinations with only one frequency carrier turned on at a time are: {1,2,3}, {1,3,2}, {2,1,3}, {2,3,1}, {3,1,2}, and {3,2,1} for a total of six. The combinations with a maximum of two frequency carriers turned on at a time are:

{(1,2),3,0}, {(1,2),0,3}, {3,(1,2),0}, {0,(1,2),3}, {3,0,(1,2)}, {0,3,(1,2)}

{(1,3),2,0}, {(1,3),0,2}, {2,(1,3),0}, {0,(1,3),2}, {2,0,(1,3)}, {0,2,(1,3)}

{(2,3),1,0}, {(2,3),0,1}, {1,(2,3),0}, {0,(2,3),1}, {1,0,(2,3)}, and {0,1,(2,3)}

for a total of eighteen. The combinations with a maximum of three frequency carriers turned on at a time are: {(1,2,3),0,0}, {0,(1,2,3),0}, and {0,0,(1,2,3)} for a total of three. Adding 6, 18, and 3 gives the total number of combinations as 27. So the total number of additional information bits is  $\log_2(27) = 4.75$ , as compared to 2.58 with the previous spectral keying scheme.

It will be appreciated by those of ordinary skill in this field, and having the benefit of this disclosure, that the amount of data encoded in a UWB symbol in accordance with the present invention significantly increases as the number of frequency carriers is increased.

In one embodiment of the present invention, as shown in Fig. 3, a method of transmitting symbols with a transmitter having a set of  $n$  frequency carriers, wherein each symbol has  $n$  modulation symbol times, includes providing 302 data to be transmitted; determining 304, based at least in part on the data that is provided, which of the  $n$  frequency carriers, if any, are to be turned on during each of the  $n$  modulation



symbol times, each modulation symbol time being of a predetermined amount of time; and turning on 306 each of the frequency carriers as determined above, during each of the modulation symbol times; wherein each frequency carrier is turned on for a period of time substantially the same as that of a modulation symbol time; and wherein each  
5 frequency carrier is turned on only once during the transmission of the symbol. The data is encoded into a symbol to be transmitted by assigning the various frequency carriers to be turned on during particular portions of the symbol, these portions being referred to herein as modulation symbol times. The method of transmitting symbols in accordance with the present invention may be referred to as enhanced spectral keying  
10 for UWB symbols.

In accordance with the present invention, a symbol, may have one or more modulation symbol times in which no frequency carrier is turned on. Similarly, in accordance with the present invention, a symbol may have at least one modulation symbol time in which at least two frequency carriers are turned on. In typical  
15 embodiments, the transmitted symbols occupy a frequency bandwidth greater than 500 MHz. In some embodiments of the present invention the transmitted symbols occupy a frequency bandwidth greater than 2 GHz. Typical embodiments include waiting for a period of time, referred to as a guard time, after the transmission of one symbol until the beginning of the transmission of a next symbol.

20 One embodiment of present invention is a method of generating information symbols including: (a) turning on, for an  $i^{\text{th}}$  predetermined length of time, during an  $i^{\text{th}}$  time period,  $x_i$  frequency carriers, where  $0 \leq x_i \leq n$ , and  $1 \leq i \leq n$ ; (b) determining whether  $n - \sum x_i = 0$ ; and (c) if the determination of (b) is negative, repeating (a) through (b); wherein  $x_i$  represents an integer number of frequency carriers. In such an  
25 embodiment, each  $i^{\text{th}}$  time period may also be referred to as a modulation symbol time, and the information symbol is made up of  $n$  modulation symbol times. In this embodiment of the present invention, the number of frequency carriers and the number of modulation symbol times are the same. In alternative embodiments, the number of frequency carriers may be represented by an integer  $n$ , and the number of modulation  
30 symbol time periods may be represented by an integer  $m$ , wherein  $n$  and  $m$  are

different. In such an embodiment, rather than determining whether  $n - \sum x_i = 0$ , one would determine whether the number of modulation symbol time periods has reached the total number  $m$  of time periods per USB symbol.

5 In typical embodiments of the present invention, the frequency carriers are turned on at the beginning of a modulation symbol time and turned off at the end of that modulation symbol time. However, in alternative embodiments of the present invention, identical temporal alignment of frequency carrier operation and modulation symbol time boundaries may not be required, but rather some accommodation is provided for recognizing a symbol wherein there is some misalignment between the  
10 time of frequency carrier operation and the modulation symbol time boundaries.

### Conclusion

Various embodiments of the present invention include methods and apparatus for providing more information in a UWB symbol, than is possible with pulse position  
15 modulation UWB, and further provides more information in a UWB symbol than is possible with previously proposed spectral keying schemes. By taking advantage of combinations of frequency carriers, the number of UWB information bits that can be transmitted within a given time can be increased without requiring additional frequency resources.

20 An advantage of some embodiments of the present invention, is that higher data rates can be achieved in a communication system in accordance with the present invention.

An advantage of some embodiments of the present invention, is that these scale exponentially as the number of available carriers increases.

25 It is to be understood that the present invention is not limited to the embodiments described above, but encompasses any and all embodiments within the scope of the subjoined Claims.

What is Claimed is:

1 1. A method of generating information symbols, comprising:  
2 (a) turning on, for an  $i^{\text{th}}$  predetermined length of time, during an  $i^{\text{th}}$  time period,  $x_i$   
3 frequency carriers, where  $0 \leq x_i \leq n$ , and  $1 \leq i \leq n$ ;  
4 (b) determining whether  $n - \sum x_i = 0$ ; and  
5 (c) if the determination of (b) is negative, repeating (a) through (b);  
6 wherein  $x_i$  represents an integer number of frequency carriers, and  $n$  represents a  
7 total number of available frequency carriers.

1 2. The method of Claim 1, further comprising:  
2 (d) if the determination of (b) is affirmative, waiting for a period of time.

1 3. The method of Claim 2, further comprising:  
2 subsequent to waiting for the period of time, repeating (a) through (c).

1 4. The method of Claim 3, wherein the period of time is a predetermined guard band  
2 that is disposed between information symbols.

1 5. The method of Claim 4, wherein the information symbols occupy a frequency  
2 bandwidth greater than 500 MHz.

1 6. A method of transmitting symbols, each symbol having  $n$  modulation symbol

2 times, with a transmitter having a set of  $n$  frequency carriers, comprising:  
3 providing data to be transmitted; and  
4 determining, based at least in part on the provided data, which frequency carriers,  
5 if any, of the set of  $n$  frequency carriers, are to be turned on during each of the  $n$   
6 modulation symbol times, each modulation symbol time being of a predetermined  
7 amount of time; and  
8 turning on each of the frequency carriers as determined in (b) during each of the  
9 modulation symbol times;  
10 wherein each frequency carrier must be turned on for a period of time not greater  
11 than the modulation symbol time; and wherein each frequency carrier is turned on only  
12 once during the transmission of the symbol.

1 7. The method of Claim 6, wherein at least one modulation symbol time has no  
2 frequency carriers turned on.

1 8. The method of Claim 7, wherein at least one modulation symbol time has at least  
2 two frequency carriers turned on.

1 9. The method of Claim 8, wherein a BPSK modulation is used.

1 10. The method of Claim 6, wherein if  $n$  frequency carriers are turned on in one  
2 modulation symbol time, then no frequency carriers are turned on in the other  $n-1$   
3 modulation symbol times.

1 11. The method of Claim 6, wherein the transmitted symbols occupy a frequency  
2 bandwidth greater than 500 MHz.

1 12. The method of Claim 6, wherein the transmitted symbols occupy a frequency  
2 bandwidth greater than 2 GHz.

1 13. The method of Claim 11, wherein the  $n$  frequency carriers transmit signals in  $n$   
2 contiguous frequency bands, and  $n$  is an integer.

1 14. The method of Claim 11, wherein the  $n$  frequency carriers transmit signals in  $n$   
2 non-contiguous frequency bands, and  $n$  is an integer.

1 15. 1. A method of transmitting ultra wideband symbols, comprising:  
2 (a) turning on, for an  $i^{\text{th}}$  predetermined length of time, during an  $i^{\text{th}}$  time period,  $x_i$   
3 frequency carriers, where  $0 \leq x_i \leq n$ , and  $1 \leq i \leq m$ ;  
4 (b) determining whether  $m$  time periods have expired; and  
5 (c) if the determination of (b) is negative, repeating (a) through (b);  
6 wherein  $x_i$  represents an integer number of frequency carriers,  $n$  represents a  
7 total number of available frequency carriers, and  $m$  represents a total number of time  
8 periods contained within each of the ultra wideband symbols.

# **ENHANCED SPECTRAL KEYING FOR WIRELESS ULTRA WIDEBAND COMMUNICATIONS**

## **ABSTRACT OF THE DISCLOSURE**

Methods provide for the amount of information encoded by spectral keying into a UWB symbol having a plurality of modulation symbol times, to be increased by operating two or more frequency band carriers simultaneously during at least one of a plurality of modulation symbol times. In one aspect of the present invention, once a frequency resource, such as a carrier, has been used during a given modulation symbol time, those frequency resources are not used again within that UWB symbol. A method of transmitting symbols, includes providing data to be transmitted, determining, which frequency carriers, if any, of a set of  $n$  frequency carriers, are to be turned on during each of  $n$  modulation symbol times, and turning on each of the determined frequency carriers during each of the modulation symbol times, and wherein each frequency carrier is turned on only once during the transmission of the symbol

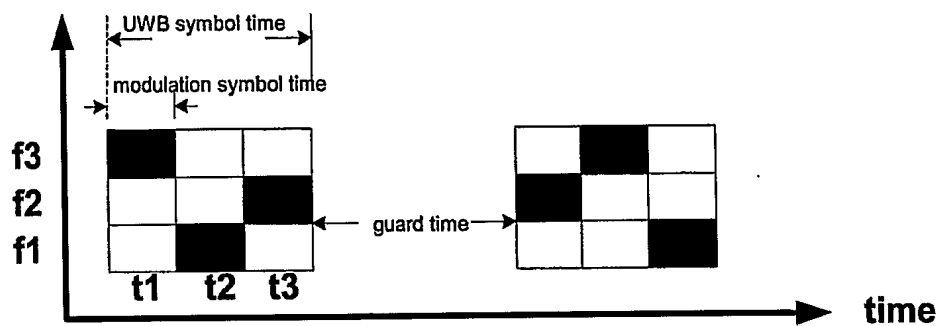


Fig. 1

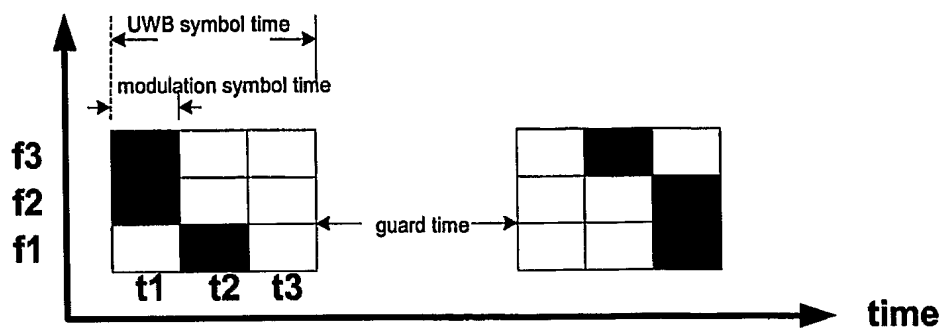


Fig. 2



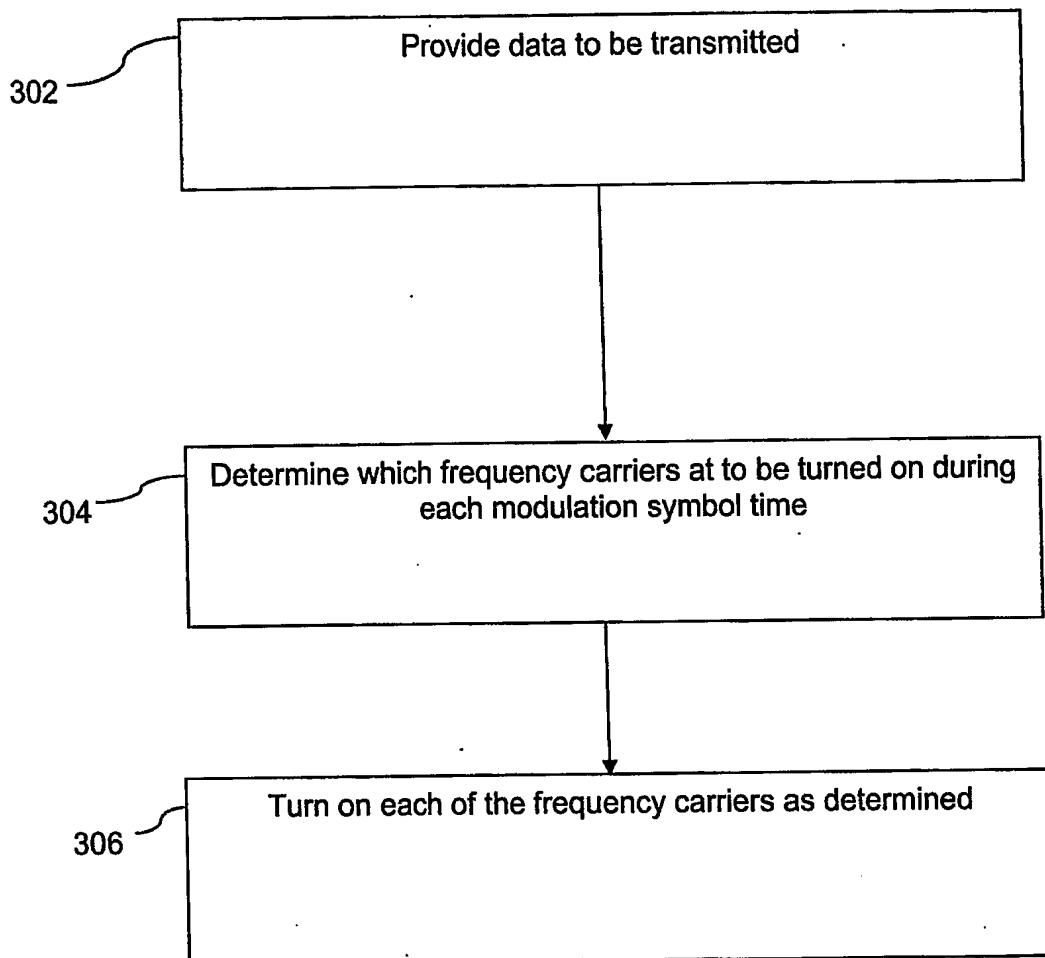


Fig. 3